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ABSTRACT

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The Struggles of Kay and Aaron: Mathematics Minors in a Constructivist Paradigm of Elementary Mathematics Instruction

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Abstract

This study investigated the struggles of two preservice elementary teachers in a mathematics methods course. Kay and Aaron elected mathematics as their content minor and indicated they had always been 'good' in mathematics. In the methods course, they were challenged to rethink the nature of mathematics learning in a constructivist paradigm. Their development of learning to teach mathematics was compared to a model originally proposed by Ammon and Hutcheson of teachers' developing pedagogical conceptions. Data sources included interviews, observations, artifacts, and assessments of mathematics teaching efficacy. Aaron and Kay entered the course with conceptions of learning mathematics as memorization of facts and procedures. Aaron continued to struggle with his belief regarding the nature of mathematics learning as "practice." Kay progressed in her desire to understand, explain reasons, and use manipulative materials. The development of these preservice teachers supported the Ammon and Hutcheson model and provided a useful framework for understanding the developing conceptions of mathematics teaching and learning for these prospective teachers.

Prospective teachers bring with them a lifetime of experiences as learners to their preservice education program. These experiences strongly influence the way they think about teaching and about the way students learn (Ball, 1988). Prospective teachers often have traditional views of what it means to teach mathematics and to learn mathematics—the teacher delivers content by prescribing specific procedures and facts that students must memorize. This philosophy of learning embedded in attitudes and beliefs about mathematics can not be ignored, but rather must be addressed when helping teachers learn to teach mathematics in new ways—that of a constructivist and developmental perspective.

The purpose of this study was to examine preservice elementary teachers' beliefs and developing conceptions of mathematics teaching and learning as they "learned" to teach mathematics. This study is based upon a working hypothesis that learning to teach in a constructivist perspective is hardest for those who were successful in a traditional mathematics

paradigm. Those individuals who were always "good" in mathematics were often good memorizers of facts and procedural knowledge rather than good in constructing rich conceptual knowledge of mathematical ideas. It is likely that these "good" mathematics students will find it difficult to change from their traditional perspective of mathematics teaching and learning to a constructivist perspective.

Background

Two theoretical perspectives framed this study: (a) a model of teachers' developing pedagogical understandings and (b) teachers' self-efficacy beliefs. These perspectives were used as lenses in which to examine preservice teachers' development of learning to teach mathematics.

A Model of Teacher Development

What is it that guides the work of teacher educators? Is there a theoretical basis to the development of teacher education programs? Is the preservice education of elementary teachers guided by practical aspects of teaching rather than by a theory of development as noted by Kroll and Black (1993)? Feiman-Nesmer and Floden (1986) claimed that no theory of teacher development existed and that many approaches to teacher change either stopped short of linking their work to a developmental theory or offered no theory for observed changes. Since that claim, a model of teachers' developing pedagogical conceptions has emerged from the work of Ammon, Hutcheson, Black, Levin, and other researchers associated with the Developmental Teacher Education program at the University of California, Berkeley (Ammon & Hutcheson, 1989; Black and Ammon, 1992; Levin and Ammon, 1992). They proposed that teachers' pedagogical understandings develop through five sequential, qualitatively different levels that begin with behaviorist conceptions of teaching and learning and progress to constructivist conceptions that are at first quite global but eventually become more differentiated and integrated. The five developmental levels of teachers' conceptions of teaching and learning are summarized in table 1. This model of teachers' developing pedagogical concepts will be referred to as the Hutcheson and Ammon model.

Table 1. Development of Teachers' Conceptions of Teaching and Learning

Qualitative Level	Goals of Instruction	Nature of Learning	Nature of Teaching
Level 1: Naive Empiricism	Acquisition of a large store of facts and procedures	Experiencing by being receptive	Showing and telling
Level 2: Everyday Behaviorism	Attainment of skills for using facts and procedures	Doing as in practicing new skills	Modeling and reinforcing by giving students practice, with corrective feedback and positive reinforcement
Level 3: Global Constructivism	Development of understandings of concepts underlying facts, procedures, and skills in a subject	Exploring relevant aspects of reality through manipulative experiences	Providing hands-on experiences by giving students opportunities to explore and manipulate developmentally appropriate materials
Level 4: Differentiated Constructivism	Improvement of conceptual understandings	Sense making and using best thinking to construct understandings consistent with present level of development	Guiding thinking within domains by engaging students in thought-provoking activities, guiding their thinking toward better understandings
Level 5: Integrated	Development of ways of thinking that can lead to better understandings	Problem solving and reflecting on general characteristics of best current thinking	Guiding thinking across domains by helping students examine their own thinking

At the first level, naive empiricism, teachers believe that children will learn if they simply show or tell them what they need to know and children will simply receive or absorb the information. Levin and Ammon (1992) noted that three of the four teachers in their multi-case study began their preservice education with a perception of teaching as providing pleasant experiences. These teachers described how children will learn if a teacher sets the stage and maintain an environment for learning while sharing knowledge and facts.

Teachers at the second level, everyday behaviorism, realize the shortcomings of just showing and telling. They now engage children in practice of specific skills and closely monitor their progress using corrective feedback and reinforcement. Teaching methods often involve the use of worksheets, games, or computer programs that provide lots of practice and reinforcement.

With the realization that practice does not lead to understanding, teachers at the third level, global constructivism, attempt to engage children self-directed discovery by providing them with

developmentally appropriate concrete materials. A teacher in a study by Levin and Ammon (1992) displayed her level three conception of teaching as she described the teachers' role in the learning process: "I think you've just got to give them as much experiences as you can, and hope that at one point or another the kids are ready for that 'ahah' experience, and then they'll get it" (p. 25).

At the fourth level, differentiated constructivism, teachers realize that children need more than just hands-on experiences, they also need to be cognitively engaged. As teachers become more adept at thinking in domain-specific ways, they are able to guide children in their sense making. The teacher may even assume a more directive role than in the previous level, except that the teacher now follows the learners' leads and attempts to provoke and guide children's thinking.

Finally, at the fifth level, teachers thinking about the process of teaching and learning becomes integrated, as well as a functional understanding of how content areas, classroom routines, and academic skills can become integrated. For example, a kindergarten teacher described how she teaches mathematics all day long integrating it into classroom routines such as calendar time and counting lunch money, to forming groups for recess activities, and so on. Teachers at this level understand how many aspects of development cut across domains.

The goal of the Developmental Teacher Education (DTE) program was to provide a strong foundation in understanding children, curriculum, and instruction from which teachers can continue to develop their pedagogical thinking beyond their preservice education through reflection on their experiences in teaching. The DTE program has assessed their teachers' pedagogical thinking as expressed in periodic interviews and their teaching practices as observed in their classrooms while in the program and after graduating from the program (Kroll & Black, 1993; Levin & Ammon, 1992). Four DTE graduates were interviewed and observed in their third year of public school teaching by Levin and Ammon (1992). They found evidence of further development in these teachers' pedagogical thinking after graduation from the program, and classroom observations indicated that their teaching practices were generally consistent with developmental and constructivist perspectives. It was also noted that there was no regression of the graduates to lower levels. It was apparent that these graduates began their teaching careers with sufficient understanding of a developmental-

constructivist perspective to maintain and extend their pedagogical conceptions, rather than experiencing the "washout" phenomena of preservice teacher education once they began working within the K–12 educational system (Zeichner & Tabachnick, 1981).

Mathematics Teaching Efficacy Beliefs

A belief is information one accepts as truth (Koballa & Crawley, 1985). An attitude is a general feeling towards something (Riggs, 1994). Beliefs form attitudes, and both beliefs and attitudes influence behavior (Bandura, 1977; Koballa & Crawley, 1985). Thus, investigating teacher beliefs is crucial to a complete understanding of teacher behavior (Riggs, 1994).

The concept of teaching efficacy derives from the work of Bandura (1977, 1981) on the construct of self-efficacy, a term Bandura employed in the context of motivation and behavior within his social cognitive theory. Deviating from the then prevailing one-dimensional view of self-efficacy, Bandura proposed that two factors influence behavior. People first develop a generalized expectancy about action-outcome expectancies via their life experiences. Second, they develop a belief about their ability to cope personally. Preservice elementary teachers approach content methods courses with formed values, attitudes, and beliefs. These include one type of belief, teacher efficacy. Teacher efficacy has two related components, personal teaching efficacy, a belief in one's ability to teach effectively, and outcome expectancy, the belief that effective teaching will influence learning (Enochs & Riggs, 1990).

Researchers (Ashton & Webb, 1986; Czerniak & Schriver, 1994; Gibson & Dembo, 1984) have found that teachers with high self-efficacy take responsibility for student learning rather than blaming poor work on the student. They also use more innovative teaching techniques, maintain a stronger academic focus in their classrooms, and involve students in decisions about classroom goals and strategies for achieving the goals. These teachers also exhibit positive feelings about their teaching, their students, and themselves.

Bandura (1977) emphasized that self-efficacy is not a general trait; it is a situation-specific belief. Ashton and Webb (1986) offered that a teacher's self-efficacy would vary according to the subject being taught or the types of students. Enochs and Riggs (1990) theorized that general

measures of self-efficacy may not accurately reflect their beliefs about their capabilities in particular subject areas, and proposed that teaching efficacy beliefs be analyzed in a subject specific manner.

In this study, the model of teachers' developing pedagogical conceptions was used as a framework for understanding the developing conceptions of mathematics teaching and learning for those prospective teachers who seem to find it the hardest to change—those who were successful in a traditional mathematics paradigm. These conceptions were also compared to an examination of prospective teachers' mathematics teaching efficacy. The following questions guided the analysis of the two cases studies.

- Does a conceptually-oriented mathematics methods course impact elementary preservice teachers development of their pedagogical conceptions of mathematics learning and teaching?
- Do a conceptually-oriented mathematics methods course impact elementary preservice teachers' mathematics teaching efficacy beliefs—mathematics teaching self-efficacy and mathematics teaching outcome expectancy?
- To what extent is the qualitative nature of the preservice teachers' thinking congruent with that predicted by the Ammon and Hutcheson model of teacher's pedagogical conceptions?
- To what extent do changes in preservice teachers' mathematics teaching efficacy correspond to changes in their pedagogical conceptions of mathematics?

Methods

This study was part of a larger investigation of preservice elementary teachers' preparation in the areas of mathematics and science, including both content and pedagogical preparation. The investigation examined two cohorts of preservice elementary teachers' beliefs and understanding of mathematics and science and of learning to become teachers of mathematics and science. The preservice teachers were concurrently enrolled in mathematics and science methods courses. When it was realized that some students had elected minors in mathematics, which is not common at this particular university, the unique opportunity arose to further examine these individuals and their development as teachers of mathematics.

Subjects

The subjects for this study were Kay and Aaron (all names used for study participants are pseudonyms). They were both undergraduate, nontraditional students in the elementary education program at an urban university. Kay, a Caucasian female, was 36 years old. She was married and had two children, ages 10 and 12. Aaron, a Caucasian male, was 32 years old. He was single and had no children. Kay and Aaron were selected as subjects for this study because they had elected mathematics as their minor content area. Each elementary education major must complete a content minor of 22 credits. The mathematics backgrounds of Kay and Aaron are shown in table 2. Both subjects completed only two years of mathematics in high school, and after returning to college, began their post-secondary mathematics coursework with a remedial algebra course. Kay and Aaron both received an "A" in this remedial course. After completing their mathematics content courses, both had achieved a "B+" average in their minor; Kay earned a mathematics GPA of 3.37 and Aaron earned a mathematics GPA of 3.31.

Table 2. Mathematics Background of Kay and Aaron

Name	Mathematics Background			
	High School	College		
Kay	Algebra Geometry	Essentials of Algebra Intermediate Algebra Elementary Functions Calculus & Analytic Geometry I Calculus & Analytic Geometry II Axiomatic Geometry Elementary Statistical Analysis Introductory Finite Mathematics 25 college credits in mathematics 3.37 mathematics GPA (4.0 scale)	A A B+ A B– C+ A B+	0 cr 3 cr 4 cr 4 cr 4 cr 3 cr 3 cr 4 cr
Aaron	Algebra Geometry	Intermediate Algebra College Algebra Trigonometry Calculus & Analytic Geometry I Calculus & Analytic Geometry II Calculus & Analytic Geometry III Math for Elementary Teachers Elementary Statistical Analysis Linear Alg & Diff Equations 31 college credits in mathematics 3.31 mathematics GPA (4.0 scale)	A A A C+ A C A P B+	0 cr 4 cr 3 cr 4 cr 5 cr 5 cr 3 cr 3 cr 4 cr

Data Sources and Procedures

All data were collected the semester the preservice teachers were enrolled in a 16-week elementary mathematics methods course and concurrently enrolled in science and social studies methods courses. Aaron was a student in the methods class in the fall semester and Kay was a student in this course with the same instructor the following semester. The methods course had an enrollment of 32 students in the fall semester and an enrollment of 30 students in the spring semester. The first author of this paper was the instructor of the elementary mathematics methods courses and the second author was a research assistant.

Data were collected from a variety of sources which utilized both qualitative and quantitative methods. These included (a) a series of individual interviews; (b) observations of the subjects in course sessions and in their fieldwork placement; (c) artifacts, such as course assignments, assessments, journal entries, and transcripts; (d) pre- and post-assessments of mathematics teaching efficacy; and (e) pre- and post-assessments of a subject teaching preference.

Semi-structured interviews were used to probed the subjects' recall of experiences that might be interpreted as affecting their beliefs about mathematics and about their ability to teach mathematics. Kay and Aaron were each interviewed three times, at the beginning of the course, towards the end of the course, and after the completion of the course. The first interview focused on the subject's experiences prior to the methods classes. They were asked (a) to discuss their reasons for becoming elementary teachers and for selecting a mathematics minor; (b) to recall memories of learning mathematics in elementary, middle, and high school, and college, and (c) to self-assess their mathematical content knowledge in relation to their future role as elementary teachers. The second interview focused on changes that occurred during the semester in terms of the subject's understanding of mathematics content and of how to teach mathematics. The third interview focused on the fieldwork component of the course—successes and frustrations in teaching mathematics to elementary school students, and on reflections regarding overall preparation to become teachers of mathematics. The interviews lasted for approximately 45 to 60 minutes each and were conducted by a research assistant. Each interview was audiotaped and later

transcribed. In order to increase participant candor, the methods instructors did not see the interview transcripts until after the completion of the semester.

The research assistant compiled field notes as she observed the methods courses regularly and observed the preservice teachers in their field placement settings. Observation of the methods course verified the nature of the methods instruction and provided opportunities to document the participation and reactions of Kay and Aaron in class discussions and activities. Fieldwork observations provided data on the preservice teachers' choices of instructional techniques; it also served as a basis for discussion in the final interview.

Artifacts were collected by the research assistant throughout the course. Artifacts included course assignments, such as reports of interviews with elementary school children, lesson and unit plans, teaching reflections. Other artifacts included journal entries, short answer and essay exam, performance tasks, portfolios, and undergraduate academic transcripts. The academic transcripts were reviewed for background information and content achievement data. The other artifacts were examined for evidence of current and changing conceptions of what it means to learn mathematics and to be a teacher of mathematics.

Teaching efficacy was measured by administering the mathematics teaching efficacy beliefs instrument (MTEBI) which was a modified version of the science teaching efficacy beliefs instrument developed by Enochs and Riggs (1990). The MTEBI consists of 21 items in a Likert scale format. Response categories include strongly agree, agree, uncertain, disagree, and strongly disagree. The MTEBI is comprised of two subscales, mathematics teaching self-efficacy and mathematics teaching outcome expectancy. The self-efficacy subscale has 13 items with a score range of a low of 13 to a high of 65 and the outcome expectancy subscale has 8 items with a score range from 8 to 40. The MTEBI was administered at the beginning and then again at the end of the course to all preservice teachers enrolled in the methods course each semester. Individual scores for Kay and Aaron on each subscale were examined and compared to the results for their respective cohort of preservice teachers.

Teaching preference was assessed by administering the subject preference inventory (Markle, 1978) at the beginning and end of the course to all preservice teachers enrolled in the methods course each semester. The inventory presents all possible pairings of eight subjects: mathematics, science, social studies, reading, language arts, music, art, and health. Respondents are to circle the subject they prefer to teach from each pair. Scores for each subject are determined by counting the number of times each subject is circled. Each subject receives a score between zero and seven. Individual scores on mathematics teaching preference for Kay and Aaron were examined and compared to the results for their respective cohort of preservice teachers.

The Methods Course

The three-credit mathematics methods course lasted for 16 weeks. Class sessions were held each Tuesday afternoon for 2 hours 40 minutes. The course was guided by the vision presented in the National Council of Teachers of Mathematics (NCTM, 1989, 1991) curriculum and teaching standards. Throughout the semester, a problem-solving and "hands-on minds-on" approach was pervasive as the instructor modeled the constructivist teaching behaviors she hoped to instill in the preservice teachers. The classroom setting, with students seated around tables, encouraged ongoing collaboration and discourse. The preservice teachers used counters, linking cubes, fraction strips, calculators, base ten blocks, tangrams, and a host of other manipulative materials to enhance their conceptual understanding of mathematics. Videotapes of classroom teaching and student interviews were used regularly throughout the course. Many opportunities were also built into the course for self-reflection; the preservice teachers wrote in math journals during each class session, reflected on student interviews and teaching experiences, and compiled portfolios.

The course shared a joint fieldwork component with science and social studies methods courses. Early in the semester the preservice teachers selected partners and indicated their preferred grade level. The two-person teams were then assigned to one classroom for the entire semester. Preservice teachers worked in elementary classrooms for approximately two hours each week for six weeks and then daily for two weeks at the end of the semester. Because the fieldwork component was shared among three courses, the instructors coordinated assignments across the

three subject areas. For example, the preservice teachers interviewed students in their placements to assess elementary students' attitudes, beliefs, and content knowledge in all three subject areas; taught separate lessons for each subject area; and than developed and taught a two-week interdisciplinary unit that had strong connections among mathematics, science, and social studies.

Results

The cases of Kay and Aaron portray the struggles of these two individuals as they dealt with conflicting paradigms of mathematics instruction—the a traditional behaviorist paradigm they had been successful with as students and the constructivist paradigm they were experiencing in the methods course and being asked to teach within during the fieldwork component. The following discussion of Aaron and Kay highlight their developing pedagogical conceptions of mathematics teaching and learning and changes in their mathematics teaching efficacy beliefs, as well as additional insights into their struggles and successes as developing teachers of mathematics.

The Case of Kay

Kay graduated from high school in 1975. She took an English course at an area technical college the following year, but did not take another course until ten years later and again it was at the same technical college. Kay worked as a certified nursing assistant and a unit secretary in hospitals and nursing homes during this time, and was also married and raising two children. Four more years passed, before she finally became a full time undergraduate student at the university with a declared intent to major in secondary mathematics education.

Kay expressed that she had always been good in mathematics, "I always had a fairly good memory for the formulas, and I loved math through algebra. Really loved it a lot. Geometry was a little hard for me." She attributed her success to her mother. Kay wrote, "I am convinced that my ability in math stemmed from my mother's ability and interest. My mother was a teacher and majored in math and science with a minor in Spanish. When I had advanced to higher levels of mathematics, algebra and geometry, I recall having to ask her for help if I got stuck on a problem. Many times if we were unable to find the answer, she would wake up in the middle of the night

because she couldn't leave the problem undone. I have had similar experiences with my calculus classes. I suddenly wake in the night and realize what I was doing incorrectly."

The first mathematics course Kay took at the university was a remedial algebra course. She commented, "It had been many years, almost 18 years, from the time I had got out of high school until I came back; so I did take the Essentials of Algebra course my first semester, because after that many years of not using it, I needed to brush up. After that, it came pretty good again." Kay received an "A" in that first course and went on to complete 25 college credits of mathematics coursework prior to enrolling in the mathematics methods course with an overall mathematics grade point average of 3.37 on a 4.0 scale.

Kay changed her major to elementary education with a minor in mathematics in the second semester of her sophomore year. She explained, "I was originally looking into high school, but then, with having to specialize, I decided that I thought the idea of being able to teach different courses, being able to integrate things on my own and stuff like that would be more interesting than just teaching the same subject every day all year long." She elaborated that a primary reason behind her change was her negative reaction to the mathematics courses she was taking at the university. Kay stated:

> I can tell you exactly why [I changed my major]. I mean I know why. It's predominantly the exposure to math here in college. The professors come out and do their thing and turn around and walk away. I saw nothing in all these courses in math that I've taken that I wanted to do for the rest of my life. I looked at it and thought "No, this isn't what I'm looking to do." And I thought, "No, just to teach math over and over and over all day long. I want to get to know the kids in a little different way." I also thought about some of the other courses that I'd be teaching [at an elementary level] and getting [students] to journal and getting them to do hands-on things and stuff like that, I would be able to get to know the kids better.

Kay's conception of teaching and learning as she entered the mathematics methods course in her senior year was characterized at level one, naive empiricism, of the Hutcheson and Ammon

model. She described the methods that allowed her to be successful in mathematics—teaching as effective showing and telling and learning as being receptive and memorizing. Kay explained, "I need it demonstrated or explained to me in some way and then I tend to remember it better. . . . I've always learned better from somebody explaining something to me, than opening a book and reading it. . . . If the teachers are clear in explaining what it is they want you to get out of it, and between what they say and my notes, my recall is far better than if I had opened a book and sat and read for an hour."

Evidence of Kay's transition to level two, everyday behaviorism, emerged as she talked about the use of calculators in learning mathematics and in helping her children with their mathematics homework. With regards to calculators, she wrote, "I would avoid the use of them in my classroom as much as possible. If in sixth or seventh grade some problems were set up for the use of calculators, I would use them. But I truly feel the students should show confidence in themselves from learning the basics and being able to do math independently." Inferring from this statement, it seems that Kay feels calculator use would prohibit mathematics learning from occurring because students would no longer have to learn or acquire knowledge of facts and procedures. A frequent topic in discussions with Kay was her experiences in helping her children, ages ten and twelve, with their mathematics homework and how she would use modeling and reinforcement to help her children.

Kay's conception of teaching and learning at level two seemed especially short lived, as she expressed, "But even when I try to explain things to my own kids, if they show me something in which they have a method at school, where I already know my method, it's hard to look at their method and understand it. I can show them how to do it in an easier way, but to understand where they are coming from, I find that a little difficult." Kay's movement toward conceptions of teaching and learning at level three, global constructivism, emerged very strongly as she expressed her desire to help her children and herself understand the concepts underlying facts, procedures, and skills. She recalled an incident in which she was asked to verbalize something, she stated, "I knew what it was, but I couldn't explain it." This was a significant experience for her because she could

not recall any previous situations in which she had been asked to verbalize her thinking and reasoning. This struggle was evident throughout the semester as Kay commented several times about her efforts to explain her reasoning in class, provide reasons to her own children, and explain during her teaching in an elementary classroom.

About this time, Kay also expressed a change in her feelings toward calculator us, "I've changed my views a lot about the use of calculators in school. I originally thought that they shouldn't be used. . . . I guess [I changed my view] because originally my thought process was that calculator use was just so students would not have to do the basic drill. I didn't see all the possibilities that you could do with the calculator." Kay also began talking about the use of manipulatives and diagrams to support learning. She noted that the mathematics lesson which she taught was "almost all manipulative."

A transition to level four, differentiated constructivism, was evident as Kay noted, "I know we never did any manipulative-type things at all with math when I was in school. . . . I can see the value of working with things, hands-on. It's just that I need to figure out how to combine the two [hands-on experiences and learning of content knowledge], so that they do the hands-on things, but they also go away with something out of it." Kay questioned whether "letting kids loose in a classroom with an activity" would really result in purposeful learning. She began to struggle in her pedagogical thinking and with her teaching as reflected in her statement, "There's things that we see in the classroom that are real interesting and even with the lessons that my partner and I taught, . . . but I don't always feel that I really left [the students] with any content. I gave them fun, hands-on stuff to do, but whether they really gained content out of what we did, I don't know."

Kay had moved beyond a conception of learning in which students just explore and the teacher just provides fun, hands-on experiences. Kay was concerned that manipulatives and diagrams be used to support domain specific learning. She described a change in her teaching as follows:

> I've noticed a big difference in the way I can make math more visual for my own kids, which I couldn't do before [this course]. And I, myself, am using different strategies at their level where before it was like, you use a system of equations and

you just do it because that's where my mental level was. Now I can look at it and think around it and ask questions.

As Kay reflected on how she was becoming better at questioning and guiding her children's conceptual understanding of mathematics, she described a particularly significant episode with her son. "His face just lit up. I mean it was an understanding like I have probably never gotten through to him before. It was really neat. I would never have been able to think about it in that way if I hadn't had this course with looking at math a little bit different."

By the end of the course, Kay's development was characterized as being at level four according to the Hutcheson and Ammon model of teachers' developing pedagogical conceptions for mathematics. Kay displayed movement away from traditional approaches in her pedagogical thinking and teaching practices and movement towards a developmental-constructivist perspective. Kay commented, "I probably would have taught the way I was taught" if she had not taken this mathematics methods course. She also cautioned, "I suppose there might be times that I would still fall back to doing that on occasion so on as they had...in part because it was always the way you were always taught. So, you know, it might come back to that at some point. But I think, I think [the instructor] has given us a lot of different insights of different ways. I've been able to explain things to my own kids a lot easier for it, and find that I am able to help them make that connection [to understanding] more often."

Some change also occurred in Kay's mathematics teaching efficacy beliefs and subject preference for teaching. Her initial score of 6 on the subject preference inventory rose to a score of 7 at the end of the semester. Thus, Kay entered and left the course feeling strongly about her desire to teach mathematics.

The overall mathematics teaching self-efficacy (MTSE) and mathematics teaching outcome expectancy (MTOE) for Kay's cohort of preservice teachers showed significant increases on both subscales (MTSE $t=-6.84$, $p<.001$; MTOE $t=-3.96$, $p<.001$). Kay's score on MTSE increased from 52 to 58 with her scores being above the cohort mean on both the pre- and post-assessments. Kay's confidence and belief in her ability to be an effective teacher of mathematics improved

throughout the semester. However, another story must be told for her MTOE. Kay's score on MTOE decreased from 30 to 29. Her pre-assessment score was slightly above the cohort mean while her post-assessment score was below the cohort mean. Kay's belief in her ability to really influence children's learning, in essence, remained unchanged. At first these results may seem contradictory, but upon closer examination they appear to be consistent with Kay's conceptions of pedagogical thinking. She described her improved ability to question and guide students learning and to provide them with hands-on and visual experiences, but she still questioned her ability to ensure that purposeful learning of content would result from her teaching. In other words, she questioned the outcome expectancy of her mathematics teaching.

The Case of Aaron

Aaron graduated from high school in 1981. He began taking college courses on a part-time basis about four years later, first at an out-of-state university and than at a local in-state technical college before enrolling in the university in 1989. Aaron had planned to major in mechanical engineering before changing his major to elementary education with a minor in mathematics.

Aaron expressed a sense of confidence in his mathematical ability and on several occasions stated, "I know math well". He wrote about two early memories of learning mathematics. Aaron first recalled how he felt smart when his older brother taught him some advanced mathematics, things like cross multiplying, which he could remember and use to show off his mathematical ability. Secondly, Aaron noted that he would often "blurt out the answer before anyone else" in his mathematics classes, which made him feel like he was good in mathematics.

The first mathematics course Aaron took at the area technical college was intermediate algebra which was considered a remedial algebra course. He received an "A" in that first course and went on to complete 31 college credits of mathematics coursework prior to enrolling in the mathematics methods course with an overall mathematics grade point average of 3.31 on a 4.0 scale. However, upon reviewing Aaron's academic transcript, it became apparent that he worked hard to achieve this grade point average by withdrawing, auditing, and even repeating some of the calculus classes.

Aaron's conception of teaching and learning as he entered the mathematics methods course was characterized at level one of the Hutcheson and Ammon model and he seemed to remain at this level for a good part of the course. Aaron mentioned how he planned to show things to his students as he reflected on his content courses in mathematics, he commented, "I think I've learned some neat stuff, little neat things that I think would be neat to show kids." Aaron also noted the importance of being able to communicate, or tell, his students information in ways that would interest and excite them. He explained, "I think I can communicate with kids, the excitement of [learning]. I think if you, no matter what you're teaching, if they're not excited about it, well, they're not going to go too far with it." He noted, "I feel that I can get them excited about it, and, hopefully, get them where their brain is turning on its own and it's not just a robot or something." Aaron commented that someone can have all the content knowledge, but still not be able to communicate with students and that is what it really means to be an effective teacher, he commented, "That's really where the rubber meets the road, I guess."

After teaching a mathematics lesson in his fieldwork classroom, Aaron reflected on the experience in a way that further confirmed his conception of teaching as showing and telling. He explained, "We did graphs. I explained how to do the circle graph. I explained it at least a few times to the kids. . . . First I did through one hundred percent, and then I said I made a mistake. But I shouldn't have said that. I should have given them the 360 and told them exactly where to draw the line." Aaron was focused on his actions and explanations and on how to communicate to the students in a clear manner exactly what they were to do. His naive conception of the requirement for learning appeared to be that students just needed to be receptive and do as they were told and they would learn.

Aaron demonstrated some change toward level two, everyday behaviorism, in his pedagogical conceptions of mathematics teaching and learning as the course progressed. He began to realize that teaching was more than just telling and showing as he discussed the need to get students to "think." Aaron described his learning of mathematics as involving memorization of facts and procedures. Aaron admitted that he was good at memorization. He explained, "The way I learned

[mathematics] was doing the same thing over and over." He commented that he had never given much thought to understanding "why" or making sense of mathematics. As Aaron reflected on the challenge being presented in the course, "the different things that she [the instructor] brought up in class on how to give the kids more of a reason why they're doing it. I don't know if it's a weakness. It's just something that's new to me." Aaron demonstrated that he was unsure whether or not it was really necessary for students to understand the procedures they were practicing. Aaron did, however, believe strongly that elementary students should not be allowed to use calculators, because, "I want the students to be able to do the problems by hand." He admitted that using calculators might be good, sometimes "but I think it's also good to use your brain—be able to use your brain without that calculator."

Glimmers of transition toward level three, global constructivism, did sparkle in Aaron's developing pedagogical conceptions of mathematics teaching and learning, but he never truly achieved this level while enrolled in the mathematics methods course. He began to realize that there might be more to mathematics than just memorizing as he struggled to understand that memorization was not true learning, even though this is how he believed he achieved success. He stated, "I think there's validity to both. There are some good things that you can learn from the old approach. . . . I think discipline is good and even coming up with schemes on memorization, although it is a lower level think skill." Aaron indicated that there was good in memorization, and than noted, "but it's better to get them thinking. Why? Tell me why. Have some reasons."

Aaron used an analogy to help explain his developing conceptions. He explained, "It seemed like I was too close to the trees, sometimes. It was like I was wishing I could just back off and see the whole picture. . . instead of trying to do all these problems, and mostly just by memorization, I guess." Aaron seemed to be expressing his own desire to learn and understand mathematics on a conceptual and how to be creative and inventive with mathematics. He stated, "I know I'm good at memorization, but it doesn't take a rocket scientist to do that. But if someone could just reason for themselves, and like engineering, create something."

By the end of the course, Aaron's development was characterized as being in transition between levels two and three. He showed some movement away from the traditional approach in his teaching, but the resistance to change was still strong. He recalled his reaction to the midterm assessment on which he had performed poorly. "Especially after the exam, walking out of there, I felt like I got hit by a Mack truck. You know, it's like wow. I'm used to a certain set way, and it's not the facilitator. It's more 'this person has all the knowledge and I'm writing it down and trying to grasp it.'" Aaron expressed that the methods course caused "a whole reworking of my brain." He explicated, "I came to be a teacher, because, like most teachers they want to help other people, I felt like maybe the public schools were lacking in certain areas, and I felt that I had something to offer. But I thought it was basically from teaching the way I was taught." Aaron acknowledged that he was still excited about becoming a teacher and admitted that "there's more to teaching than standing up in front and being a lecturer."

Some changes also occurred in Aaron's subject preference for teaching and mathematics teaching efficacy beliefs. Aaron's initial mathematics score on the subject preference inventory was 4. This declined to a score of 3 at the end of the semester. Aaron displayed only a moderate preference to teach mathematics as compared to other subject areas and his experiences with the methods course apparently caused him to rethink and question his originally preferences.

The overall mathematics teaching self-efficacy (MTSE) and mathematics teaching outcome expectancy (MTOE) for Aaron's cohort of preservice teachers showed significant increases on both subscales (MTSE $t = -4.98$, $p < .001$; MTOE $t = -2.83$, $p < .01$). Aaron's scores on both subscales, in essence, remain unchanged. His score on the MTSE increased from 49 to 51 and decreased on the MTOE from 31 to 30. His initial scores on both subscales were slightly higher than the cohort means, while his post-assessment scores were below both cohort means.

Aaron's beliefs in his ability to be an effective teacher of mathematics and in his ability to really influence children's learning remained unchanged throughout the semester. These results show evidence of the internal conflict Aaron was experiencing with his conception of teaching and learning

mathematics. He continued to question his own understanding of mathematics and what it means to teach mathematics, and consequently was unsure if his teaching would impact student learning.

Discussion

Kay and Aaron entered the elementary mathematics methods courses feeling good about their mathematical ability and levels of mathematical content knowledge. Both had elected mathematics as their content area minor and had achieved a "B+" average in their mathematics content courses. Kay and Aaron also had similar measures of mathematics teaching self-efficacy and mathematics teaching outcome expectancy. The similarities between these two individuals soon ended.

Kay made great strides in her developing pedagogical conceptions of mathematics teaching and learning as compared to the Ammon and Hutcheson model. Kay progressed from level one, naive empiricism, quickly to level three, global constructivism, and eventually to level four, differentiated constructivism, by the end of the course. Aaron, on the other hand, entered the course at level one and seemed to remain at level one for much of the course. He eventually progressed to level two, everyday behaviorism, and even showed glimmers of transitioning to level three, but never reached a level of understanding conceptions of teaching and learning from a constructivist perspective.

The conceptually-oriented mathematics methods course did impact these elementary preservice teachers' development of their pedagogical conceptions of mathematics learning and teaching and the qualitative nature of the preservice teachers' thinking seemed congruent with that predicted by the Ammon and Hutcheson model of teacher's pedagogical conceptions. However, even though the two preservice teachers entered the course with similar backgrounds, they did not develop at the same rate. In using a model of teacher development, teacher educators are challenged to meet the individual needs of their preservice teachers. Aaron received a passing grade in the mathematics methods course, but should he continue to receive support and assistance until he has established a stronger foundation upon which to continue his development of pedagogical thinking in the area of mathematics teaching and learning?

It seems that the difference in the development of Kay's and Aaron's pedagogical conceptions in mathematics can primarily be attributed to one factor—Kay's opportunity to work closely with her two children on almost a daily basis. Kay spoke frequently of these experiences as she was interviewed, during class discussions, and even in conversations with the instructor and research assistant. Kay's ability to listen to her children and follow their lead while guiding their mathematical thinking improved tremendously throughout the semester. Teacher education programs should think carefully about the types of fieldwork components that are used and how these can be matched to the developmental needs of preservice teachers. With Aaron's conception of teaching at the level of naive empiricism, he designed and taught lessons that reflected this level of understanding—he showed and told. It would seem that he would have benefited far more from opportunities to work closely with one or two students in efforts to understanding how they think and reason about mathematics.

The conceptually-oriented mathematics methods course significantly impacted Kay's mathematics teaching self-efficacy, but not her mathematics teaching outcome expectancy. The course did not impact Aaron's mathematics teaching efficacy beliefs as the scores on each subscale, in essence, remained the same. This findings are particularly interesting in light of the fact that their respective cohorts made significant gains on both mathematics teaching self-efficacy and outcome expectancy. Upon closer examination, the changes or lack of changes in Kay's and Aaron's beliefs of mathematics teaching efficacy did correspond to the changes in their pedagogical conceptions of mathematics teaching and learning. Kay and Aaron entered the course with higher than average scores on both subscales and both acknowledged that they assumed they would eventually be teaching mathematics in a manner similar to how they learned mathematics, from a traditional behaviorist perspective. As their conceptions of mathematics teaching and learning were challenged, they had to rethink their own "successful" experiences in mathematics and learn to teach in a new way, that of a constructivist paradigm of elementary mathematics instruction.

Summary

Preservice teachers who were successful in a traditional mathematics paradigm often struggle with teaching in a constructivist paradigm. This study offered insight into the development of prospective teachers who often find it hard to change by examining the struggles of two preservice elementary teachers with mathematics minors as they were learning to become teachers of mathematics. These preservice teachers both demonstrated a strong mathematical background based on their achievement in mathematics content courses and they both noted they had always been "good' in mathematics. However, they had been "good" in a traditional paradigm of mathematics instruction which involved rote memorization of rules and procedures. In the mathematics methods course, they were continually challenged to rethink the nature of mathematics learning and teaching in a constructivist paradigm.

Kay showed strong growth in her developing conceptions of mathematics teaching and learning toward a developmental-constructivist perspective. However, Aaron struggled much more than Kay and only made slight progress in his understanding of learning to teach in a constructivist paradigm of mathematics instruction. It is likely that Kay has established a strong foundation upon which to continue her development of pedagogical thinking beyond her preservice education through reflection on her experiences in teaching. It also appears almost equally likely, that without further support and reflective experiences in learning to teach mathematics, the progress Aaron has made may be "washed out" and he could regress in his pedagogical conceptions of learning to teach mathematics.

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